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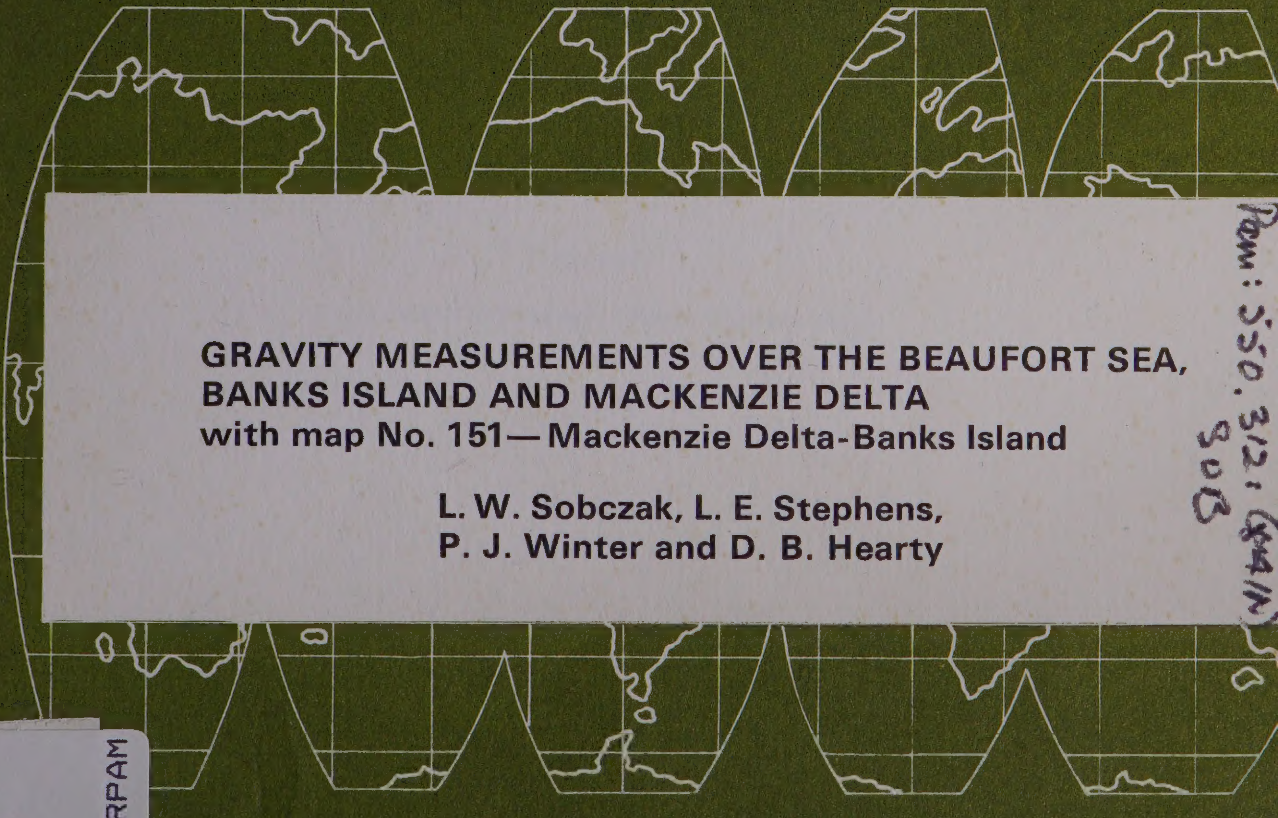

# GRAVITY MEASUREMENTS OVER THE BEAUFORT SEA, BANKS ISLAND AND MACKENZIE DELTA
with map No. 151—Mackenzie Delta-Banks Island

L. W. Sobczak, L. E. Stephens,
P. J. Winter and D. B. Hearty



RTMENT OF ENERGY, MINES AND RESOURCES
CANADA 1973

GRAVITY MAP SERIES

of the

EARTH PHYSICS BRANCH

Ottawa

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# and

# MACKENZIE DELTA

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# GRAVITY MEASUREMENTS OVER THE BEAUFORT SEA, BANKS ISLAND AND MACKENZIE DELTA

L.W. Sobczak, L.E. Stephens, P.J. Winter and D.B. Hearty

ABSTRACT - The Earth Physics Branch has made about 7,700 gravity measurements over the Beaufort Sea, Banks Island and Mackenzie Delta between 1969 and 1972. Measurements were made both on land and on the sea ice of the Beaufort Sea. The major feature of the free air gravity anomaly map is an arcuate high of about 100 mgal which is one of many elliptical anomalies along the continental margin. These anomalies are explained by a thinning of the crust at the continental break.

The Bouguer anomaly field over Banks Island is highly variable with anomalies varying from +30 to -40 mgal along northerly trends. These anomalies may be related to Precambrian basement structure of the Prince Patrick Uplift. Bouguer anomalies east of the Mackenzie Delta reveal a spectacular circular positive anomaly of 115 mgal located south of Darnley Bay. The source of this anomaly has been attributed to a buried intrusion. Generally, however, extensive gravity lows in the Kugmallit Bay and Mackenzie Bay areas are underlain by thick clastic sedimentary sequences.

The land and ocean regions of the map area are near isostatic equilibrium as shown by the mean free air anomaly of 5.5 mgal. This suggests that major extensive sedimentary basins may be compensated while local basins 50 km wide or less maintain a distinct gravity expression.

RÉSUMÉ - La Direction de la physique du Globe a effectué entre 1969 et 1972, tant sur terre que sur la glace de mer, environ 7,700 mesures gravimétriques dans la mer de Beaufort, l'île Banks et le delta du Mackenzie. L'accident majeur de la carte des anomalies à l'air libre forme une courbe positive d'environ 100 mgals et l'une des nombreuses anomalies elliptiques le long de la marge continentale. Ces anomalies s'expliquent par un amincissement de la croûte à la limite continentale.

Le champ d'anomalies de Bouguer sur l'île Banks, extrêmement variable, comporte des anomalies de +30 à -40 mgals le long d'axes à direction nord. Ces anomalies peuvent être reliées à la structure précambrienne du socle du soulèvement Prince Patrick. Les anomalies de Bouguer à l'est du delta du Mackenzie révèlent une spectaculaire anomalie circulaire positive de 115 mgals au sud de la baie Darnley. L'origine de cette anomalie est attribuée à une intrusion enfouie. En général, cependant, de vastes minimums gravimétriques dans les régions des baies Kugmallit et Mackenzie résultent d'épaisses successions clastiques sédimentaires sous-jacentes.

Les zones terrestres et océaniques sur la carte sont presqu'en équilibre isostatique comme l'indique l'anomalie moyenne à l'air libre de 5.5 mgals. Cet état amène à l'hypothèse d'une compensation des vastes bassins sédimentaires, tandis que des bassins locaux de 50 kilomètres de large ou moins conservent une expression gravimétrique distincte.

## INTRODUCTION

The Gravity Division of the Earth Physics Branch, as a participant in the Polar Continental Shelf Project (P.C.S.P.) of the Department of Energy, Mines and Resources, has recently extended regional gravity surveys over the Beaufort Sea, Banks Island and the Mackenzie Delta. The P.C.S.P. supports and coordinates diverse scientific activities in the north most of which are manned by federal agencies. From 1959 to 1968 the P.C.S.P. concentrated survey efforts in the Queen Elizabeth Islands and the neighbouring Arctic Ocean while operating from two main base camps at Isachsen and at Mould Bay. However, in response to demands from government and from the oil industry for landmass information in the Mackenzie Delta and surrounding regions, the P.C.S.P. in 1969 moved the main supply base from Mould Bay to Tuktoyaktuk.

Between 1969 and 1972 nearly 5,000 gravity observations were made at intervals of about 6 km over the sea ice of the Beaufort Sea. The history of these measurements is summarized in Table I which lists, by year of operation, the number of gravity stations established, the instruments used and the names of the observers. In addition, during the same period many observations were made on land over the Mackenzie Delta and Banks Island. The results of these measurements have been published (Hornal, Sobczak, Burke and Stephens, 1970; Stephens, Sobczak and Wainwright, 1972). Since 1960, the Americans have made over 800 gravity measurements over the entire Arctic Basin (Wold, Woodzick and Ostenso, 1970). These results outline a belt of elliptical free air anomalies over the continental break that joins the trend of gravity highs off the Queen Elizabeth Islands (Sobczak and Weber, 1973).

TABLE I

History of additional Surveys over the Beaufort Sea

| Year | No. of Gravity Stations | Instrument No. | Personnel |
|---|---|---|---|
| 1969 | 903 | G 172<br>G 173<br>W 573 | L.W. Sobczak<br>L.E. Stephens<br>P. Fernandez-Davila |
| 1970 | 1550 | G 172<br>G 173<br>W 573 | L.W. Sobczak<br>L.E. Stephens<br>P.J. Winter |
| 1971 | 1525 | G 172<br>G 173<br>G 25A | L.W. Sobczak<br>D.B. Hearty<br>J. Over |
| 1972 | 982 | G 256<br>G 278 | L.W. Sobczak<br>R. Beach<br>J. Over |

In this report we present the combined results of all federal gravity surveys within the region bounded by latitude 68°N to 75°N and longitude 115°W to 141° W as delineated in Figure 1. Maps have been published for some areas (dotted) and other areas (hachured) contain unpublished new data.

Field procedures and the accuracy of measurements are briefly described although these have been discussed earlier (Sobczak and Weber, 1970) and apply equally to the measurements made over the Beaufort Sea. Emphasis in this report is placed on problems of navigation and bathymetry. In 1971 the position of the ocean camp was independently determined from celestial fixes which allowed a comparison between these positions and those determined from


Figure 1. Location of Mackenzie Delta - Banks Island survey covered by gravity map, GMS 151. Previously published data is indicated by the 'dotted area' and new gravity data by the 'hachured area'.

the Decca Lambda chain reduced at various speeds of propagation. Matthews' relationship (1939) for obtaining depths in sea water was checked using Wilson's relationship (1960a and b). All temperature, pressure, and salinity measurements taken over the Arctic Ocean and processed with the Oceans IV program (Sweers, 1970) were utilized in this analysis.

## REGIONAL SURVEYS

### *Logistics*

Large turbine helicopters, Bell 204B and 205A, were used primarily for long range traverses working from the ocean camps located about 300 to 480 km north of the Mackenzie Delta (Figure 2). A small piston driven helicopter (Bell 47G4A) was used from 1969 to 1971 along the coast and out to sea about 70 miles. In 1972 this helicopter was replaced by a small turbine helicopter (Bell 206B, jet ranger) which performed exceptionally well for our type of survey; it carried two observers, Decca equipment, emergency supplies and still had a working period ($4\frac{1}{2}$ to 5 hours) similar to the working period of the larger turbine helicopters. Costs and logistic support were cut by a factor of two. The same station production was maintained. Minor inconveniences in the helicopter included cramped quarters and inadequate heating; at temperatures below -10$^{\circ}$F, the heating system was inadequate.

Ocean camps were established on smooth floes of old thick polar ice by P.C.S.P. hydrographers seconded from the Inland Waters Branch of the Department of the Environment. These camps were shared by the gravity survey party for about six weeks during March and April. Ocean camp supplies were brought in by ski-equipped single and twin-engine Otter aircraft and Bristol Freighter on balloon tires. The camps consisted of three 16 x 20 foot Parcoll huts which served as office, mess and sleeping quarters for a party of about 12 (two pilots, two aircraft engineers, four hydrographers, two or three gravity observers, one cook and one or two camp labourers).

The ocean-ice camps moved randomly in a clockwise direction in general accord with the overall movement of water in the Arctic Ocean (Figure 2). In 1969 (from March 26 to April 18), in 1970 (from February 24 to April 25) and in 1971 (from March 18 to April 7) respectively the camp moved 176 km (110 miles) westward, 390 km (244 miles) more or less westward, and 50 km (31 miles) southward. In 1969 and 1970 continual easterly winds accounted for the large distances travelled. The westward movement of the ocean camp assisted in surveying the area with a minimum of ferrying time because the survey was done from the east to the west as the camp moved westward.

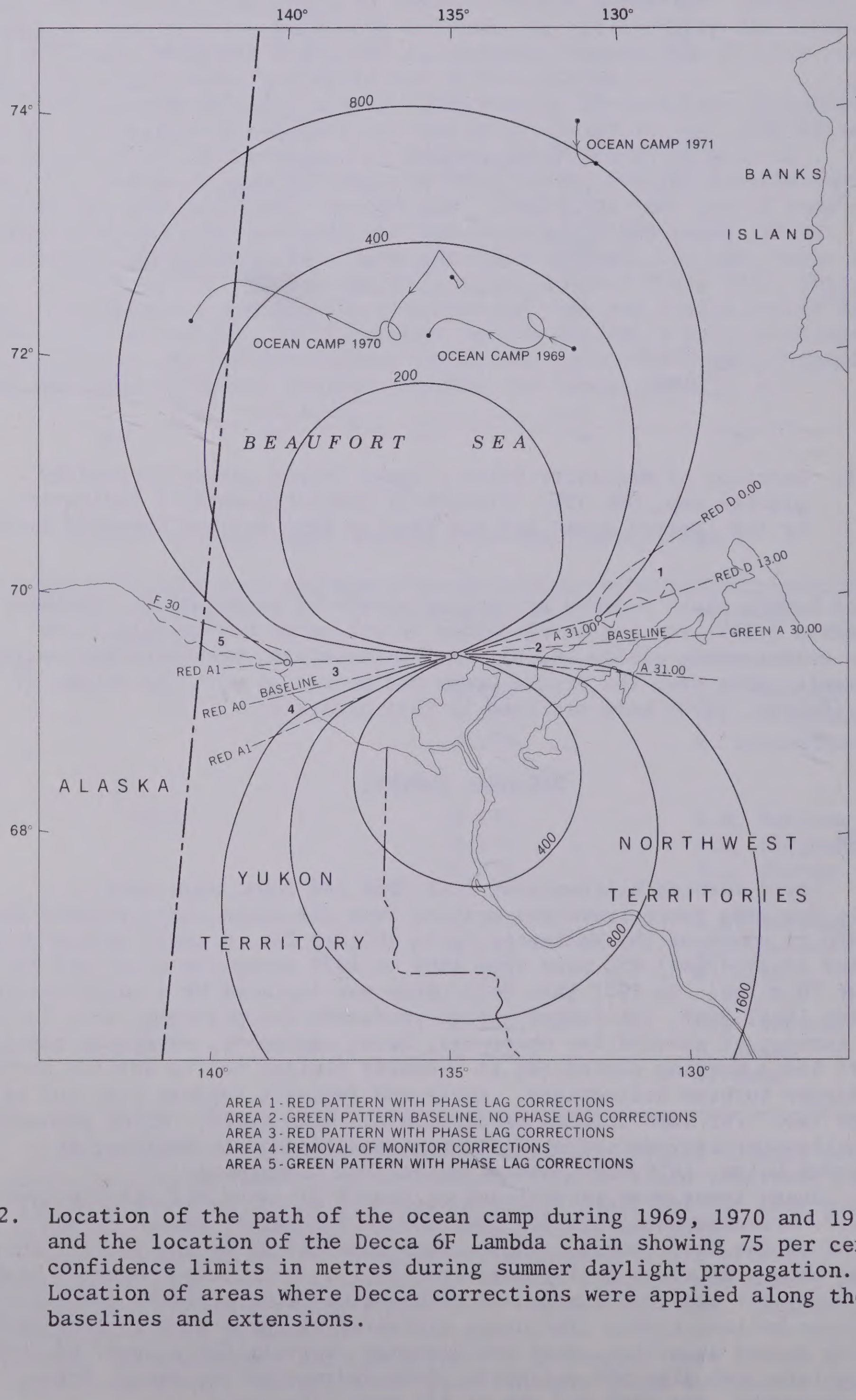


Figure 2. Location of the path of the ocean camp during 1969, 1970 and 1971 and the location of the Decca 6F Lambda chain showing 75 per cent confidence limits in metres during summer daylight propagation. Location of areas where Decca corrections were applied along the baselines and extensions.

*Gravity Measurements*

A network of control stations tied to the National Gravity Net was established on land using LaCoste-Romberg gravimeters. After adjustment by a Gauss-Seidel iterative method, the standard deviations of the gravity values were generally less than 0.05 mgal. Station descriptions and gravity values are available upon request from the Gravity Division, Earth Physics Branch, Ottawa. A plot of these control stations is shown in Figure 3. All regional sea ice stations are related to these land base stations; no permanent control stations were established on the ocean because of the drifting sea ice and the difficulty of relocating original points.

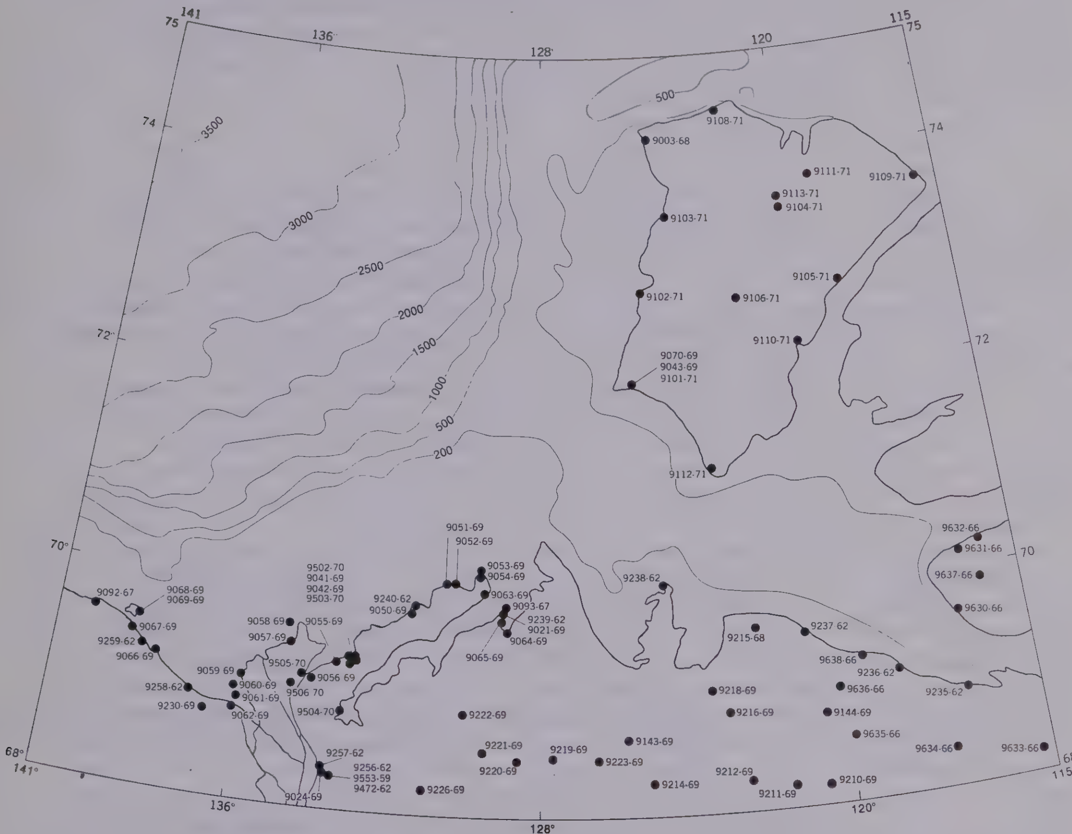

Figure 3. Location of gravity control stations within area covered by gravity map, GMS 151. Bathymetric contours are in metres.

Most of the regional gravity measurements on the sea ice were made with miniature LaCoste-Romberg gravimeters which were usually damped. These gravimeters were carried in aluminum cases with specially built vibration isolators which minimized gravimeter drift. In addition a two-inch layer of foam and a layer of horsehair padding were used during flights in the large helicopter (Bell 205A) to eliminate large drifts or tares of up to 0.3 mgal per day. It was found in 1969 that the new gravimeters G173 and G172 drifted nearly 2 and 4 mgal respectively in 27 days. In the following years checks were made every one to two weeks at a land control station. The maximum drift encountered subsequently was 0.5 mgal in 14 days.

A temperature-controlled, damped Worden gravimeter was used along the delta from shore out to about 110 km. Measurements were made on a 12-km grid. However, in 1972, when the station density was increased to a 6-km grid, it was found that about 5 per cent of the Worden measurements had to be discarded because of errors which ranged from 2 to 15 mgal. The reason for these large

errors was apparently due to unusually large motions of the sea ice which caused stop-to-stop oscillation of the gravimeters. This problem was not normally encountered with the damped LaCoste-Romberg gravimeter used exclusively in subsequent surveys.

Detailed gravity surveys (station spacing 3 km or less) were conducted in three areas on the sea ice. A calibration line consisting of 30 gravity stations, spaced at 3-km intervals about 60 km north of Atkinson Point, was established with a Worden gravimeter (W573) to calibrate the shipborne meter gravity on board the Baffin from the Bedford Institute of Oceanography. An area of 30 km x 30 km about 100 km north of Atkinson Point was also surveyed in detail to locate a shoal reported by the Manhattan the previous year and also to provide an alternative area for shipborne gravimeter calibration. A small area about 130 km northwest of Herschel Island was surveyed to obtain more detailed information over an intense local negative gravity anomaly. Gravity measurements taken on the sea ice during these detailed surveys are believed accurate to ±0.3 mgal.

*Elevation and Water Depth Measurements*

Methods of measuring elevations and depths and determining their accuracies have been discussed in other publications (Sobczak *et al.*, 1970, and Stephens *et al.*, 1972). Elevations over the Mackenzie Delta have estimated standard error of ±3 m and ±8 m over Banks Island. Some vertical control measurements on Banks Island were determined by an Airborne Profile Recorder (APR) technique. Errors in excess of 15 m were discarded from these measurements before adjustment by a Gauss-Seidel iterative method.

Most of the water depths beyond the continental shelf were measured by the hydrographers using a Gifft Sounding System which was designed for Arctic use in deep water (Jollymore, 1971). This system was tested and performed very well in 1969. However, in 1970 and 1971 it was either inoperative for long periods or performed poorly. A new improved system has subsequently been proposed by the Earth Physics Branch.

Water depths on the shelf in shallow water, 200 metres or less, were either determined by an Edo 9040 echo sounder or interpolated from hydrographic charts. In 1969 and 1970 when the Bell 47G4 helicopter was used on the shelf, water depths were interpolated with an accuracy of at least ±15 m. However, in 1972, when the same area was resurveyed using a Bell 206 helicopter all depth measurements were made using an Edo 9040 echo sounder. These high precision acoustic sounders measure travel times to an accuracy of ±1 msec corresponding to a depth of ±0.7 m. On rare occasions over rough or wet ice the sounders had a scatter in measurements up to ±5 msec. All travel times were converted to water depths using Matthews' tables (1939) which may introduce errors of ±2 per cent in water depths. For deep water say 3,000 m or more an error of ±2 per cent in depth would introduce an error of ±60 m corresponding to an error of ±4.1 mgal in the Bouguer anomaly. Errors of this magnitude could not be tolerated and pointed to an urgent need for a more precise water-velocity relationship or at least verification of Matthews' relationship.

This problem was overcome in 1971 by using Wilson's equation (1960a and b), to obtain a desired accuracy of ±0.1 per cent. Wilson's relationship programmed by Sweers (1970) allowed us to compute sound velocities in sea water at various depths using data compiled by the Canadian Oceanographic Data Centre for 3,000 stations in the Arctic Ocean. Interval velocities were derived at 0, 100, 200, 500, 1,000, 1,500, 2,000, 2,500, and 3,000 m. However, velocities for the interval 0 to 500 m had a large scatter probably because of the greater mixing of sea water and fresh water during the summer when many of the measurements were made. Thus oceanographic measurements taken from the sea ice during the AIDJEX program in 1970 were used instead to compute velocities at depths of 30, 60, 100, 140, 180, 220, 260, 300, 350, and 500 m. All interval velocities were integrated and compared with Matthews' (1939) and Crary and Goldstein's (1957) velocity relationships (Figure 4). Figure 4 shows that, in general, Matthews' relation gives velocities which are about 0.2 per cent

lower than the more acceptable velocities determined from Wilson's relation. This small difference would produce errors in depth at 3,000 m of less than ±6 m corresponding to an error in Bouguer anomaly of about ±0.3 mgal which is considered negligible.

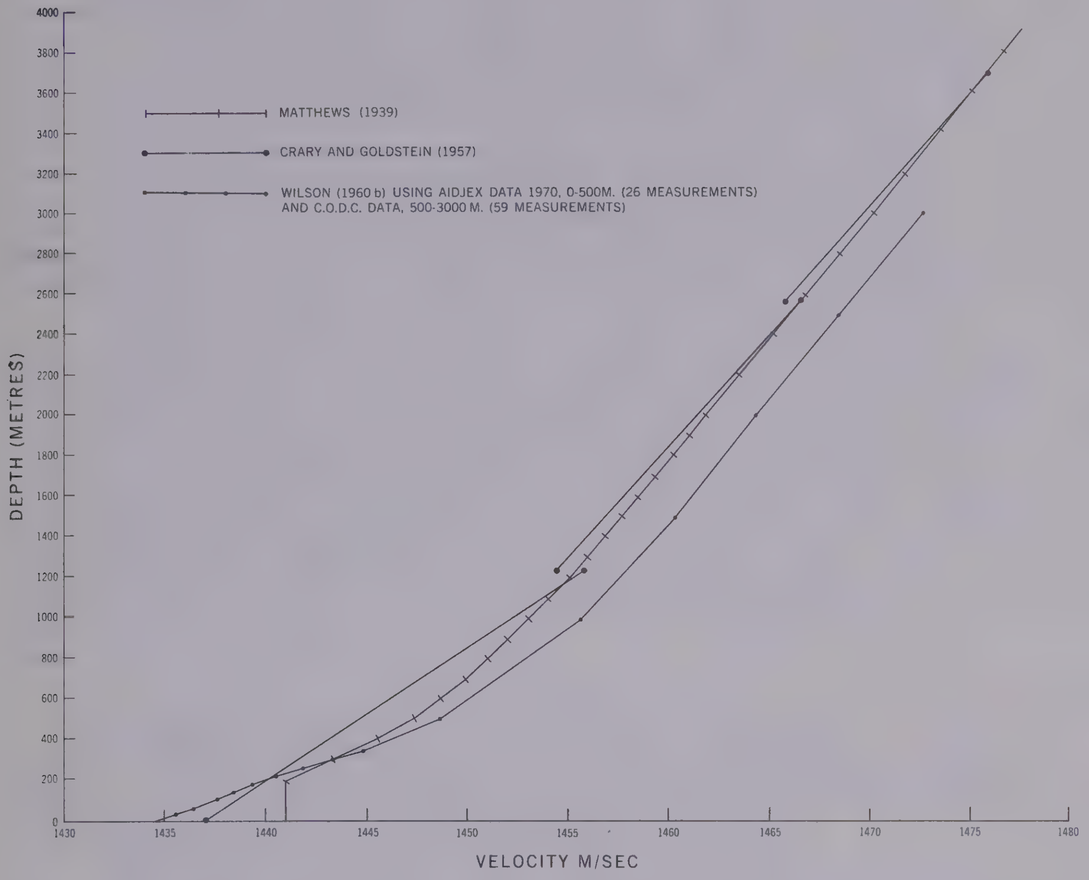


**Figure 4.** Curves showing the relationship between water depths in metres and integrated velocities in metres/sec for the Arctic Ocean.

*Determination of Position*

Land stations were selected at identifiable locations by 1:250,000 topographic maps. These positions were scaled to an accuracy of about 100 m but errors of 300 m may be present at a few stations observed on Banks Island; snow over low topographic relief obliterated features early in the season which normally would be easily recognizable (Stephens *et al.*, 1972). If these positional inaccuracies were in latitude they would contribute errors of ±0.05 to ±0.15 mgal in the gravity anomalies.

Sea ice stations were positioned by a Decca 6F Lambda survey system which has been described by the International Hydrographic Bureau (1956). Figure 2 shows the location of the Decca chain, the 75 per cent confidence limit in metres during summer daylight propagation as published by the manufacturers, and areas where corrections were applied along the baselines and baseline extensions.

*Evaluation of the Decca System*

In 1971 Decca and celestial fixes for the ocean camp were compared (Sobczak, 1971). Previous attempts to evaluate the Decca system over the sea ice have never revealed any significant difference from the predicted values.

In 1959 a tellurometer - theodolite traverse of 120 km over the sea ice failed due to the drifting pack ice which made closures unreliable. In 1967 seismologists experienced positioning discrepancies of up to 10 km northwest of Prince Patrick Island. Anderson and Mahaffy (1969) made sun shots at 20 locations throughout the Decca pattern to check its accuracy. Their results gave a mean difference between Decca and astronomical positions of about 1,000 m. However, their own measurements showed considerable scatter. In 1971 at the ocean camp near the outer limits of the Decca coverage (Figure 2) comparisons between astro and Decca positions revealed that the velocity of propagation used in the reduction of Decca had to be lowered to a velocity of 299,400 km/sec from a value of 299,650 km/sec (a value calculated on the baseline) in order to get better agreement between Decca and celestial fixes. Over 1,000 Decca measurements and 28 astro fixes were taken. The astro fixes were computed by Lamont - Doherty Geological Observatory and are reliable to 0.16 km or better (Hunkins, 1971). Positions determined from the Decca and astro measurements grouped into three areas. Mean variation of positions in these areas decreased from 2.9 and 6.4 km to 1.8 and 3.6 km respectively when the velocity of propagation was reduced to 299,400 km/sec. Although a better fit could be obtained by varying the speed of propagation from about 299,550 to 299,150 km/sec during the field season, this was not done because the results represent only one area of the Decca coverage and not enough is known about other areas. Perhaps the velocities vary over the area as well as during the season.

Baseline areas present a special problem and require special treatment because errors in Decca positions for known points on land along the baselines and baseline extensions varied from 0 to 13 km. In order to avoid such distortions, phase lag corrections were applied to the baseline areas (Figure 2). Positions in these areas are probably only reliable to ±4 km and may introduce an error in the gravity anomalies of ±2 mgal.

### *Reduction of the Data*

The gravity observations were reduced to free air and Bouguer anomalies using the method described by Tanner and Buck (1964). For the Bouguer anomalies sea water was replaced by an equivalent layer of rock with density 2.67 g/cm$^3$. These anomalies include the inaccuracies which have already been discussed. In addition, the anomalies include small errors from other sources such as Eötvös and terrain effects. The Eötvös effect is caused by reading on the moving sea ice and is usually less than 0.1 mgal. Removal of the Eötvös effect was not done because of the difficulty of determining the velocity and direction of movement of the sea ice at each gravity station. Terrain effects were also omitted. Over the Beaufort Sea these effects are less than 2 mgal (Hornal *et al.*, 1970) and over Banks Island less than 5 mgal (Stephens *et al.*, 1972).

## GEOLOGICAL SETTING

The region is divided into six structural - physiographic regions: The Canada Basin, Arctic Continental Shelf, Arctic Coastal Plain, Arctic Lowlands, Interior Plains and Cordilleran Region (Figure 5).

*The Canada Basin* is an old ocean basin flanked by the Franklinian and Brooks Range geosynclines and is underlain by a thick sedimentary section. The continental slope is fairly uniform dipping to the northwest. The average gradient is about one degree between depths of 200 to 1,000 m and about half a degree beyond this depth. This is significantly less than the gradient of 4.5$^o$ found off Alaska.

An extensive physiographic feature known as the Beaufort Terrace a large plateau (300 km long and 150 km wide) rising 610 m above the bottom is shown on small scale maps of the Canada Basin (Douglas, 1970) and on a bathymetric chart (Gebco chart 897, 1967). However, the Beaufort Terrace *does not* exist. This is clearly demonstrated by a bathymetric map published earlier by Wold *et al.* (1970) and by the map shown in Figure 5.

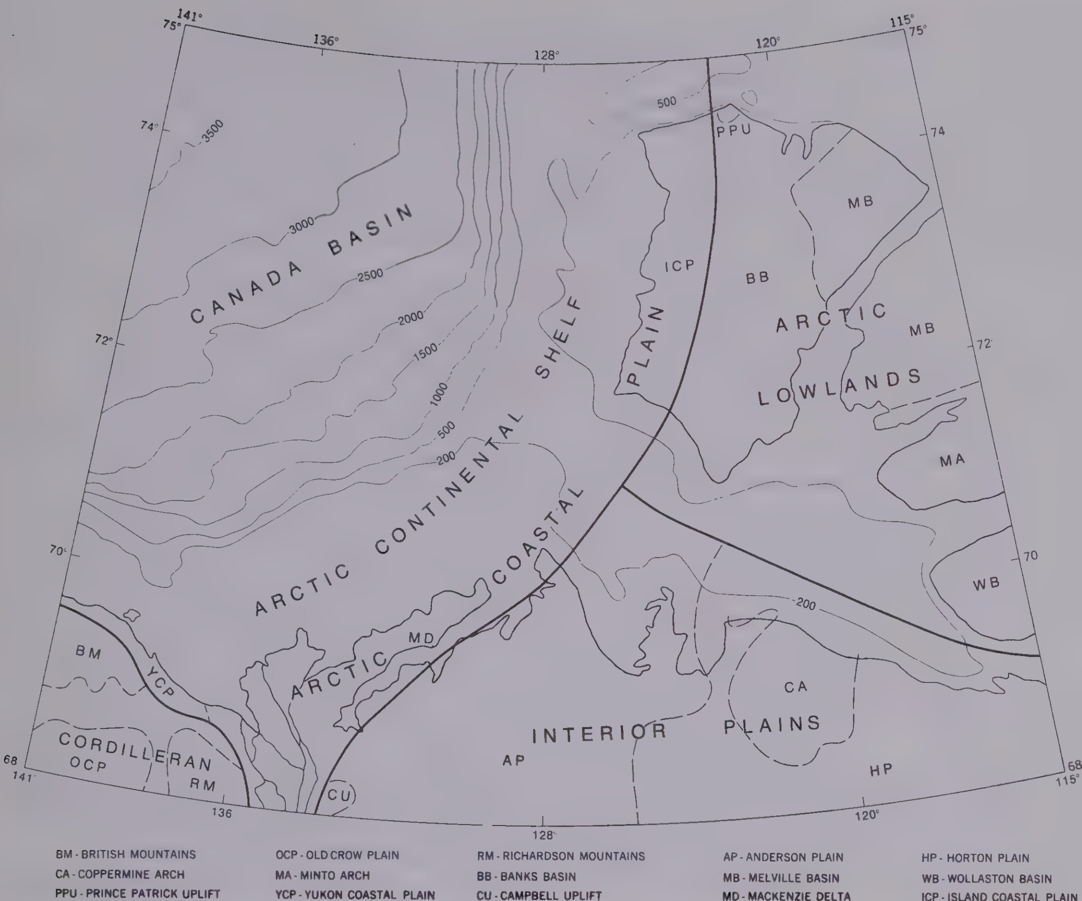


Figure 5. Generalized geological and bathymetric map. Water depths are in metres.

*The Arctic Continental Shelf* in the Beaufort Sea is a typical continental shelf; the continental break occurs near the 200 m isobath on a shelf about 150 km wide. However, the shelf is not typical to either side. To the west the shelf narrows to about 70 km and the break occurs at a depth of 60 m. To the north (i.e., west of Banks Island) the location of the break shifts to progressively greater depths to a maximum of 400 metres. Much further to the northeast the break occurs at a depth of about 650 m off Ellef Ringnes Island (Sobczak *et al.*, 1972).

The shelf area receives huge volumes of sediments. It is estimated that the Mackenzie River annually transports 80 million tons of sediments as solids and in solution and that another 30 million tons may be delivered by the smaller streams bordering on the Beaufort Sea (Wold *et al.*, 1970). This total volume is equivalent to that delivered by the Mississippi River. Sediments frozen in the ice may be transported long distances out over the Canada Basin.

The Arctic Continental Shelf is flanked by the *Arctic Coastal Plain* which borders the Arctic Lowlands, Interior Plains and Cordilleran regions. It is composed of Tertiary nonmarine sands and gravel of the Beaufort Formation which dips oceanwards. These deposits are at least 75 m thick on the northwestern Arctic Islands and 335 m thick in the Mackenzie Delta (Douglas, Norris Thorsteinsson and Tozer, 1963). They may represent the edge of marine sediments of the Arctic Continental Shelf.

Structural features are only prominent in the older exposed regions, the Arctic Lowlands, Interior Plains and the Cordilleran regions. Within the vicinity of the map area the *Arctic Lowlands* is divided into two basins, the Melville Basin to the northwest and the Wollaston Basin to the southeast by a

Precambrian salient, the Minto Arch. The gravity field in the Melville Basin has not been mapped except for a small part in the north underlying Banks Island. Ordovician to Devonian carbonates are the principal rocks of the Lowlands and are thickest to the north in the Melville Basin, (Douglas *et al.*, 1963). Cretaceous and Tertiary sands and shales of Banks Basin unconformably overlie Paleozoic carbonates and Precambrian rocks. North-trending faults and folds in the southern part of Banks Island may connect with the north-trending structures in the northern part of Banks Island. Douglas *et al.* (1963; 1970) suggested the possibility that the Prince Patrick Uplift may be continuous across Banks Island.

*The Interior Plains* are underlain by flat-lying Phanerozoic sediments. In the area outlined in Figure 5, the Plains are divided into two regions called the Horton and Anderson Plains. The Horton Plain, with the oldest exposed bedrock is underlain by nearly flat lying Paleozoic and Proterozoic sediments of the Wollaston Basin. The central part is uplifted by the north-trending Coppermine Arch which is on strike with the Prince Patrick Uplift. Basic intrusions consistently strike northwest along the Arch. The Anderson Plain is underlain by Cretaceous and Devonian sediments in a regional homocline that dips gently to the west. The western region is deformed by a north-trending arch centred along the Kugaluk River and an uplifted region south of Sitidgi Lake called the Campbell Uplift which forms the eastern part of the Aklavik Arch. The lower sedimentary section (Middle Devonian and lower) is dominated by dolomite and is overlain by late Middle Devonian and Cretaceous shale.

*The Cordilleran Region* is very complex. Northwesterly trending structures of the British Mountains and Old Crow Plain which formed the easternmost part of the Brooks Range geosyncline plunge below the Cretaceous structures of the Richardson Mountains perhaps as far east as the West Channel of the Mackenzie River. The British Mountains and Old Crow Plain were uplifted, folded and intruded by granitic masses before the Carboniferous. These movements closed the Brooks Range geosyncline and welded it to the Yukon stable block (Jeletzky, 1961). Then the Mesozoic trough of the Richardson Mountains formed across the Paleozoic structural grain of the eastern end of Brooks Range geosyncline. A northerly trend of folds developed in the Richardson Mountains in post-mid-upper Cretaceous time.

## GRAVITY ANOMALY FIELD

A Bouguer anomaly map (GMS 151) at a scale of 1:1,000,000 is enclosed. Generalized Bouguer and free air anomalies are shown superimposed on the geology and bathymetry in Figures 6 and 7. A map was compiled to show Bouguer anomalies over land areas and free air anomalies over sea (Figure 8). This map emphasizes the trends due to structural features better than a Bouguer anomaly or free air anomaly map for the area.

The Bouguer anomalies have a range of more than 160 mgal, varying from less than -60 mgal over Mackenzie Bay to more than 100 mgal south of Darnley Bay. Anomaly trends are generally parallel to physiographic-structural boundaries. Anomaly highs generally occur along arches and uplifted regions and lows are underlain by basins and plains.

Free air anomalies over water also have a range of more than 160 mgal, varying from less than -60 mgal over Mackenzie Bay to more than 100 mgal at the continental break. Anomaly trends are again parallel to the coastline. Anomaly lows occur over the shelf and at the base of the slope areas. An arcuate string of positive elliptical anomalies straddles the continental break.

### *Discussion of Anomalies*

Considered as a whole, the area is close to isostatic equilibrium. A mean free air anomaly of 5.5 mgal was determined from 7,666 stations over the Beaufort Sea, Mackenzie Delta and Banks Island. However, several significant anomalies and anomaly trends at the mouth of the Mackenzie River are probably uncompensated and are related to near surface structures.

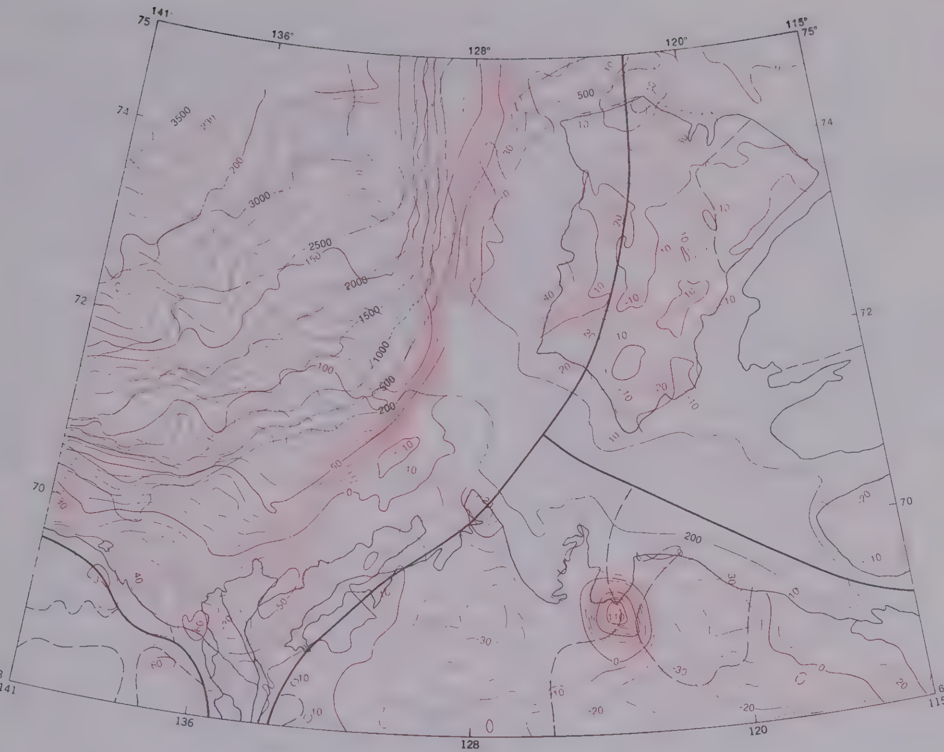


Figure 6. Generalized Bouguer anomaly map of the Beaufort Sea, Banks Island and Mackenzie Delta superimposed on the geology and bathymetry. Gravity contours (red) are at intervals of 10 mgal. Water depths are in metres.

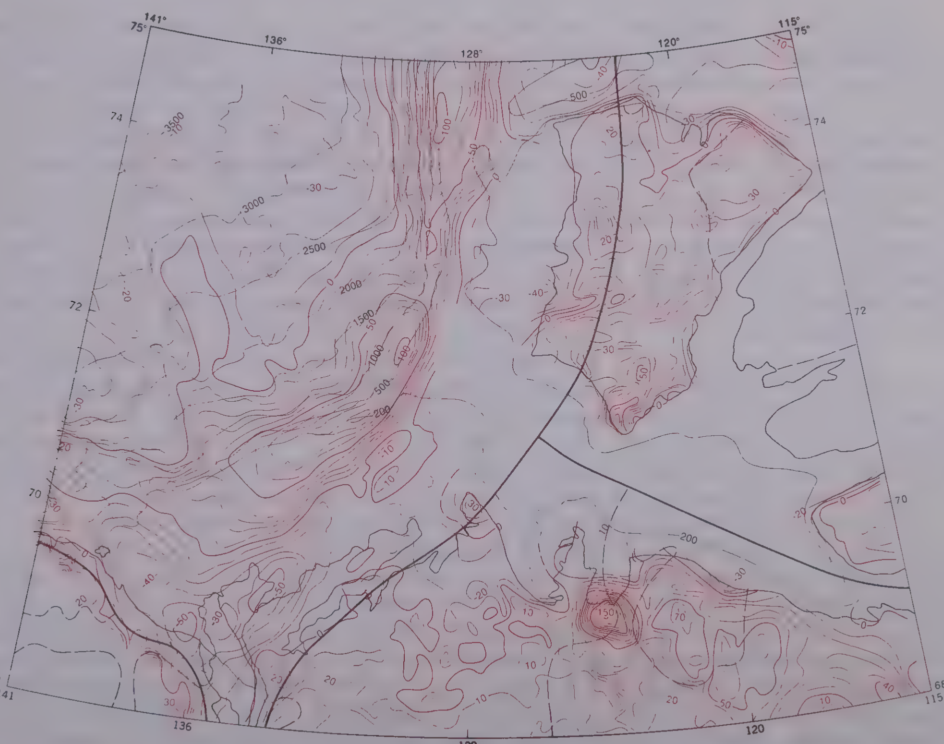


Figure 7. Generalized free air anomaly map of the Beaufort Sea, Banks Island and Mackenzie Delta superimposed on the geology and bathymetry. Gravity contours (red) are at intervals of 10 mgal. Water depths are in metres.

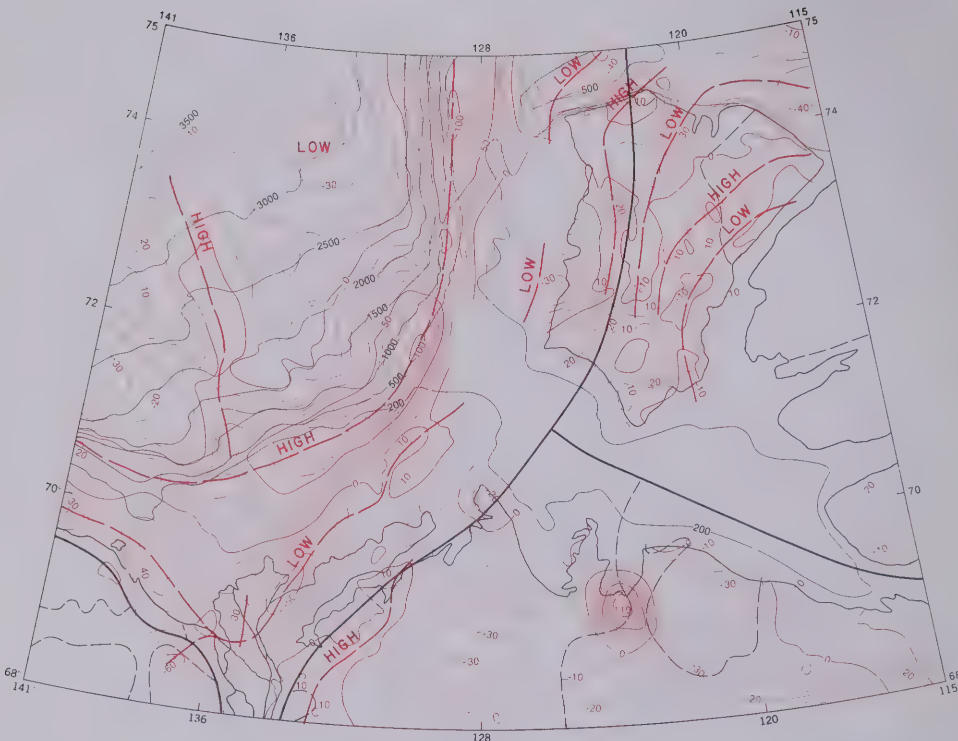


Figure 8. Generalized combined gravity map with Bouguer anomalies shown on land and free air anomalies shown over water. Gravity field superimposed on the geology and bathymetry. Gravity contours (red) are at intervals of 10 mgal. Water depths are in metres.

*Offshore Anomalies.* The major feature of the gravity field is the zone of positive elliptical anomalies (>100 mgal) at the continental break. This zone is flanked by gravity lows over the Canada Basin and Arctic Continental Shelf. It is parallel to the coastlines of Banks Island, the mainland and the Arctic Coastal Plain. Wold *et al.* (1970) have interpreted these anomalies as the combined effect of crustal thinning from an overall level of 35 km landwards to about 20 km below the ocean and a variation in the thickness of near surface clastic sediments. A ridge in the basement occurs below the gravity highs and thick basins of low density sediments underlie the lows. This explanation is in accord with results found by Weber (1963) and Sobczak and Weber (1973) for the same anomalous zone off the Queen Elizabeth Islands (Figure 9).

*Anomalies on land.* Bouguer anomaly trends on land are not as prominent or as continuous as the free air anomalies over water. Obvious trends which lie parallel to the offshore anomalies have been joined (Figure 8). The remainder of the anomalies may be linked into parallel trends but in some places these trends are truncated by small cross trends as in southern Banks Island along Big River and on the mainland in the Liverpool Bay area.

The eastern side of the Arctic Coastal Plain is flanked by a belt of gravity highs which may be in part related to a thinning of clastic sediments over an arch of carbonate rocks or crystalline basement or due to the edge effect of a stable Precambrian platform as mapped by Riddihough *et al.* (1973). Commencing in the south over the Mackenzie Delta and proceeding northwards over Banks Island there is a high of +10 mgal over the Campbell Uplift at the eastern end of the northeast-trending Aklavik Arch, +10 mgal over the Kugaluk Arch at the mouth of the Kugaluk River, +30 mgal south of Baillie Islands and a series of highs varying from +10 to +30 mgal on Banks Island probably delineating the western limit of the Prince Patrick Uplift. The high south of Baillie Islands

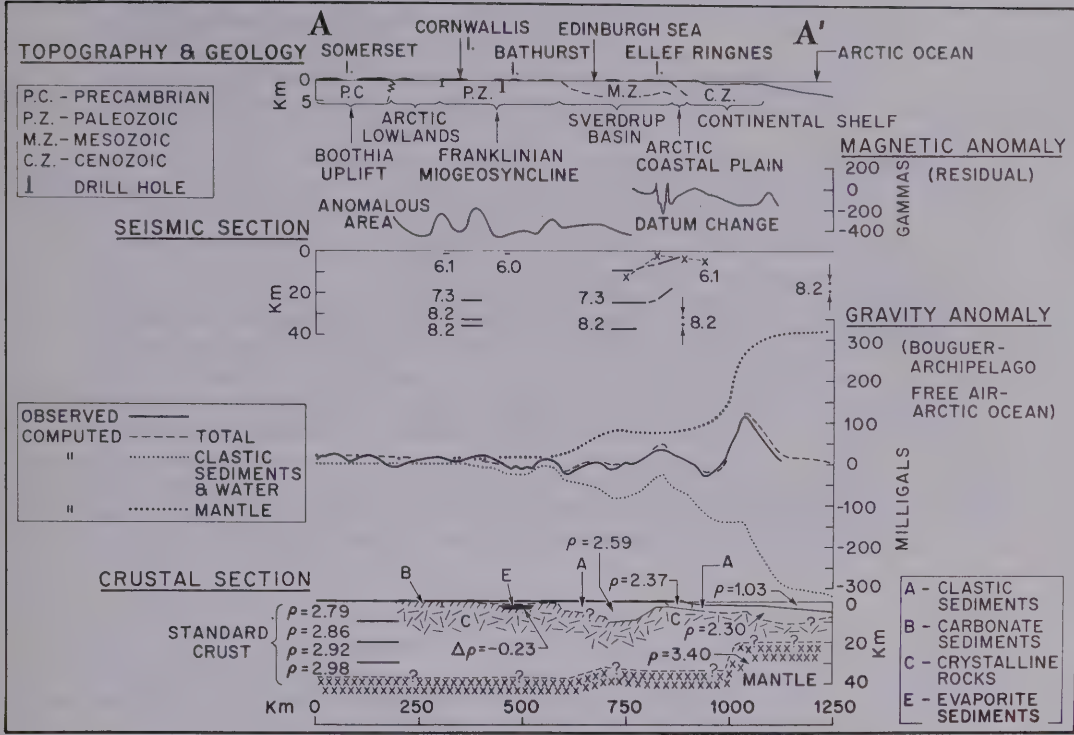


Figure 9. A north-south crustal section from Somerset Island to the Arctic Ocean used to illustrate a probable cause for the positive elliptical anomalies over the continental shelf (Sobczak and Weber, 1972).

(see map GMS 151) probably relates to a basic intrusion similar to the high south of Darnley Bay (Hornal *et al.*, 1970). These anomalies lie close to the eastern boundary of the Arctic Coastal Plain from where the formations gently dip seaward and the proposed edge of the stable Precambrian platform (Riddihough *et al.*, 1973). Immediately east of this boundary on Banks Island is a parallel zone of lows (varying from 0 to -35 mgal) through the centre of Banks Island and Banks Basin. On the mainland there is a low of -35 mgal over the central part of the Anderson Plain. These lows probably reflect thickening of low density Cretaceous and Tertiary clastic sediments over a predominantly Paleozoic carbonate and Precambrian basement. Further eastward, the remaining gravity highs and lows may be similarly related to variations in thicknesses of low density clastic sediments over high density carbonates and Precambrian crystalline basement. Density contrasts between 0.3 and 0.5 g/cm$^3$ would account for anomaly variations from 12.6 to 20.9 mgal per km of thickness. A relative anomaly variation of 50 mgal could be explained by changes in thicknesses from 2.5 to 4 km.

The north-south trends of anomalies on Banks Island coincide with the Prince Patrick Uplift, but, north of Banks Island over M'Clure Strait, the trends turn eastward on strike with the Parry Islands Fold Belt of the Queen Elizabeth Islands rather than continue across to Prince Patrick Island where the Prince Patrick Uplift is apparent on the surface. This eastward trend north of Banks Island coincides with the eastward trend of the stable Precambrian platform (Riddihough *et al.*, 1973) and anomalies may reflect the edge effect of this platform.

Centred over Kugmallit Bay and Mackenzie Bay are two elliptical extensive lows (minimum -50 mgal) which coalesce just west of the West Channel of the Mackenzie River and trend inland southwesterly along the westerly flank of the Richardson Mountains. Hornal *et al.* (1970) suggested that thick Tertiary and Cretaceous clastic sediments could account for the low over Kugmallit Bay. A 130-km-long seismic reflection profile (Hofer and Varga, 1972) southeast of Herschel Island which crosses the westerly end of the low over Mackenzie Bay

suggests at least 2,700 to 3,700 m of clastic sediments where the anomaly is estimated to be at least -30 mgal. These values support the estimates by Hornal *et al.* (1970). It is interesting to note that, if the anomaly lows are a reflection of the thickening of low density clastic sediments, then the thickest deposits extend inland below the Richardson Mountains, a former Mesozoic basin.

A northerly-trending relatively positive anomaly of 30 mgal underlain by the Middle Channel of the Mackenzie River is aligned with the Donna River Fault to the south and with a positive residual anomaly of 20 mgal to the north which trends towards the central part of the Canada Basin. To the south this high may represent a horst or an uplift of Precambrian rocks and Paleozoic carbonates within the Cretaceous and Tertiary sediments as found farther south along the same fault (Jeletzky, 1961). To the north similar structures may persist. The rectangular characteristic of the anomaly suggests a horst or ridge-like structure which may continue through the centre of the Canada Basin.

Approximately 120 kilometres north of Herschel Island are two small, but important anomaly lows (see map GMS 151). These anomalies are concentric with relative lows of 10 to 14 mgal and about 6 km wide and are associated with physiographic features which rise about 300 to 500 m above the floor of the ocean which is at a depth of about 1,500 to 1,900 m in this region. They may outline low density salt or gypsum intrusions and warrant further investigation.

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